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Synthesis and characterization of tin oxide thin films: A review

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ABSTRACT

Tin oxide thin films have many advantages such as chemical inertness, high transparency, highly electrical conductive, and high temperature resistance. Up-to-date, numerous works have been reported by many scientists concerning SnO_2 films using various deposition methods such as atmospheric pressure chemical vapour deposition method, electro deposition, chemical bath deposition, ultrasonic spray pyrolysis method, pulsed laser deposition method, magnetron sputtering method, and thermal evaporation method. The obtained films were investigated using different analysis tools such as x-ray diffractometer, scanning electron microscopy, UV-visible spectrophotometer and FTIR spectrometer. This study sought to elucidate the effects of the various deposition conditions on the morphological, structural, optical properties of SnO_2 films.

Keywords: tin oxide, thin films, deposition, semiconductor, solar cells.

INTRODUCTION

Interest in metal oxide thin films and metal chalcogenide thin films[1-38]as components in optoelectronic and semiconductor industry has grown recently. Tin oxide thin films have received much attention over the past few years due to these films have a wide range of properties including chemical inertness, mechanical hardness and high temperature resistance.

The aim of this work is to prepare tin oxide films by using various deposition methods. The obtained films were used for characterization studies such as structural, morphological, optical and electrical behaviors. The band gap was obtained from absorption spectra.

Literature survey:
Thin films of tin oxide have many potential applications in smart window, phototransistor, flat panel display, solar cells, light emitting diodes, transparent electromagnetic shielding materials and infrared heat mirror. They have many unique properties such as wide band gap, transparency to visible light and *n*-type conduction behavior.

Saikia et al [39] proposed to prepare tin oxide films on glass substrate using atmospheric pressure chemical vapour deposition method. XRD studies indicate that as deposited films have a tetragonal structure and highly oriented along the (110) plane. Four-probe method and Hall voltage measurement experiments give useful information regarding the electrical properties of films. The films indicated conductivity in the range 108 to 169 $\Omega^{-1}cm^{-1}$.

Yang et al (40)have synthesized SnO_2 films on fluorine doped tin oxide glass using electro deposition method from aqueous solutions containing $SnCl_2$, HCl and butyl rhodamine B (BRhB).BRhB was used as a structure directing agent to control the growth of films during the experiment. The scanning electron microscopy (SEM) micrographs of the films prepared in the absence of BRhB revealed irregularly connected nanoparticles randomly stacked in large domain. On the other hand, it can be seen that many smaller particles produce a larger porous particle with an

average diameter of 50 nm for the addition of 100 µM and 20 nm for 150 µM BRhB solutions. In another case, the electrodeposited SnO_2 films were characterized using X-ray diffraction (XRD) technique as discussed by El-Etre and Reda[41]. The XRD data show that the film is SnO_2 with tetragonal rutile structure. The average grain size about 24 nm, which was determined using the Scherrer equation. The particles indicate homogeneity in size and nearly spherical shape as shown in surface morphology studies. Chen et al [42]suggested a novel deposition technique to prepare SnO_2 films. The films were deposited on copper substrate by one step electrodeposition without the pretreatment of electrolytes. An effect of deposition potential on the morphological properties was investigated using scanning electron microscopy. Smaller grains and thinner films were obtained on the surface of SnO_2 films at deposition potential of 0.6 V (versus standard hydrogen electrode) if compared to other conditions.

Tin oxide thin films have been grown by pulsed laser deposition method as reported by Dolbec et al[43]. They claim that the SnO_2 films deposited on alumina and quartz substrates consisted of pure polycrystalline SnO_2 phase and were almost stoichiometric. On the other hand, SnO_2 films with a thickness between 1000-2000 Å were successfully deposited on glass substrate as prepared by Phillips et al[44] using the pulsed laser deposition. They point out that the films grown using Sn target exhibit a relatively high transmittance of 80% in the visible region. Meanwhile, X-ray diffraction patterns of pulsed laser deposited SnO_2 films at different stages of post deposition annealing were investigated by Fan and Reid [45]. They conclude that the formation of the litharge of SnO and orthorhombic phase of SnO_2 are clearly visible at intermediate temperatures.

The effects of oxygen partial pressure percentage in the range of 1% to 10% on the magnetron sputtered tin oxide films have been studied by Leng et al [46]. The results indicate that introduce of oxygen would suppress the deposition process and the growth of films. They found that the film resistivity reduces with the increase of oxygen pressure as indicated in electrical measurement. Lastly, they observe that the SnO_2 films with resistivity of 232 Ωcm were obtained in pure argon atmosphere. On the other hand, the obtained as-deposited magnetron sputtered SnO_2 films were submitted to thermal annealing and exposed to butane gas as described by Stedile et al [47]. The highly disordered as-deposited films are modified under thermal processing and gas exposure, changing the oxygen vacancy concentration as could be observed in their experiment. They conclude that these behaviors should affect the steady state response of tin oxide sensors. Electrical measurements have been investigated by Giulio et al [48] on sputtered SnO_2 films at various anneal temperatures. The variation of the Hall mobility and conductivity with the annealing temperature could be attributed to increase in the grain size and to reduce in the oxygen vacancies of the SnO_2 thin films after heat treatment process. Czapla et al [49]prepared SnO_2 films using reactive sputtering technique. The obtained results reflect that the excess tin atoms locate in interstitial positions of the tetrahedral crystal. They discover that the deviation from stoichiometry strongly affects the optical transmittance and changes the values of refractive indices as well.

The influence of substrate temperature on the properties of SnO_2 films deposited by ultrasonic spray pyrolysis method was reported by Achour et al [50]. The average crystallite sizes and band gap energies were increased from 6.52 to 29.8 nm, and 4.03-4.133 eV, respectively with increasing substrate temperature from 400 to 500 °C. The films show high transmittance (75 %) in the near infrared region (at more than 800 nm), thereby making them a very good material for warming applications.

Tin oxide thin films have been prepared by thermal evaporation method as reported by Jahnavi et al[51]. They observe that band gap energy increases with an increasing annealing temperature for SnO_2 films. UV-visible transmission spectra of these films indicated that high transmittance of 99% in the visible region. Thermally evaporated SnO_2 films of thickness in the range 100-600 nm were successfully deposited onto glass substrate at ambient temperatures by Shadia [52]. The XRD pattern reveals that these films are amorphous. It was observed from the SEM micrograph study that the surface of the film is smooth, uniform and well covered with the material. Lastly, energy dispersive x-ray analysis (EDAX) indicated that these films are deficient in oxygen.

SnO_2 films were prepared by chemical bath deposition method at 55 °C using tin chloride pentahydrate in aqueous medium. High quality SnO_2 films with transmittance more than 80% in the visible region are observed by Khallaf et al[53]. Annealed films are orthorhombic, highly stoichiometric, strongly adhesive and transparent with band gap about 4.4 eV. Chemical bath deposited tin oxide films were prepared on glass substrate with stannous chloride and urea as the precursor and buffer in aqueous medium. The peaks respond to the (110), (101) and (211) planes of rutile structure could be observed in XRD pattern. The influence of stannous chloride concentration and weight ratio of urea/water on the properties of chemical bath deposited SnO_2 was investigated by Rifai et al[54]. The increasing of $SnCl_2$ concentration and the reducing weight ratio of urea/water is observed to improve the crystallinity of the SnO_2 films. Chemical bath deposited SnO_2films have been prepared onto soda lime glass substrate in the presence of tin chloride and methanol solution as reported by Yusuf et al [55]. The Scherer formula was used to calculate the grain size. It is interesting to note that the average grain size was observed to be 29.6 nm, which increased to 30.04 nm

after annealing in air at 400 °C. In the transmission spectra, optical transmittance was about 80 % in the visible range. SnO_2 films were prepared on microscopic glass slide using the chemical bath deposition method as described by Suresh and Jiban [56]. The chemical bath contains tin chloride, hydrogen peroxide, deionized water, triethanolamine and ethylenediaminetetraacetic acid solution. Deposition was carried out about pH 7 and at 110 °C. The average crystalline size was about 18 nm. SEM studies reveal that the grains are well defined, spherical and of almost similar size (16 nm). Finally, the Fourier transform infrared spectroscopy (FTIR) spectrum displays the strong presence of SnO_2.

CONCLUSION

Tin oxide thin films have been successfully prepared by using various deposition methods. The morphology, structure, composition and optical properties have been investigated by using different tools during the experiment. The obtained results reflect that the various deposition conditions have great influence on the properties of SnO_2 thin films.

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